

# Blade Design Codes

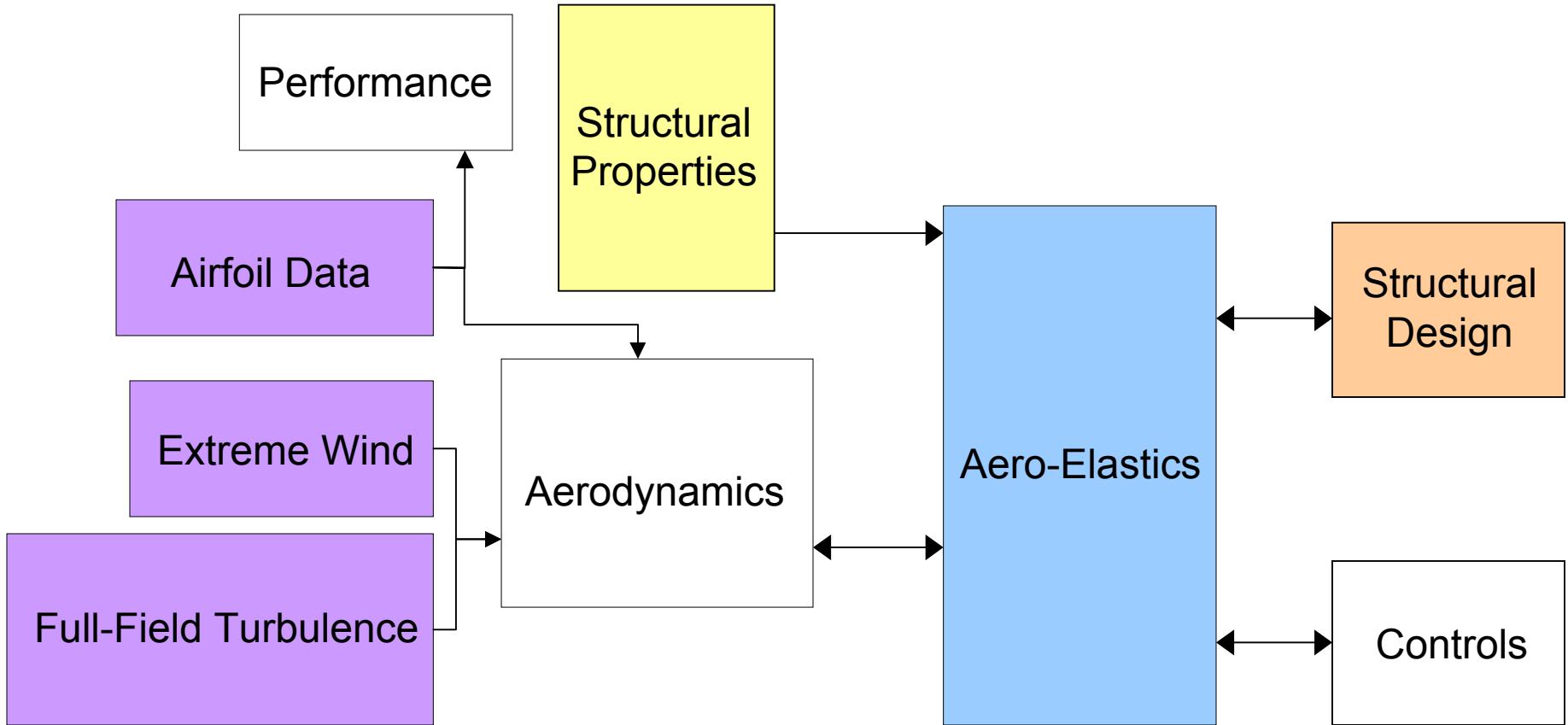
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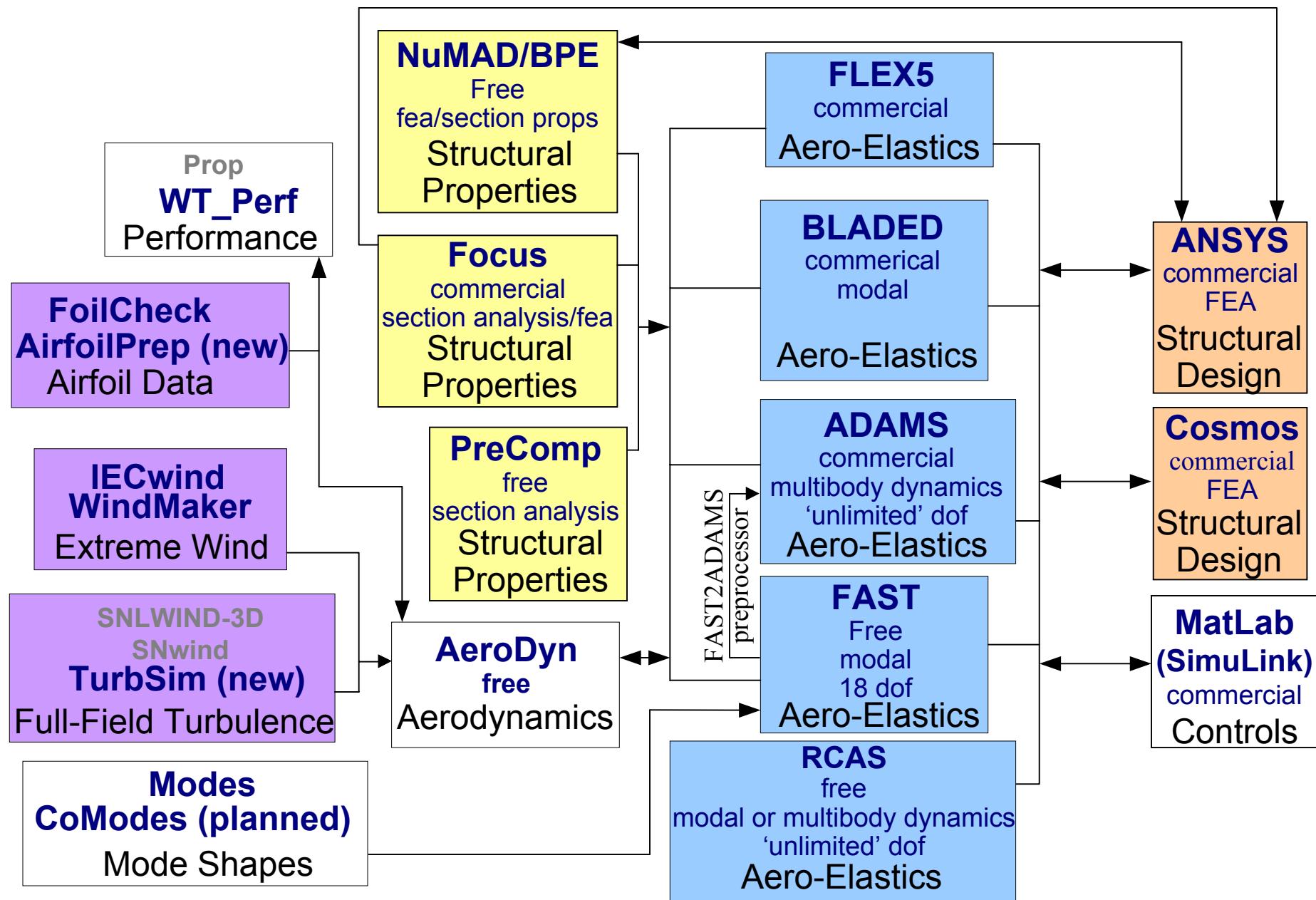


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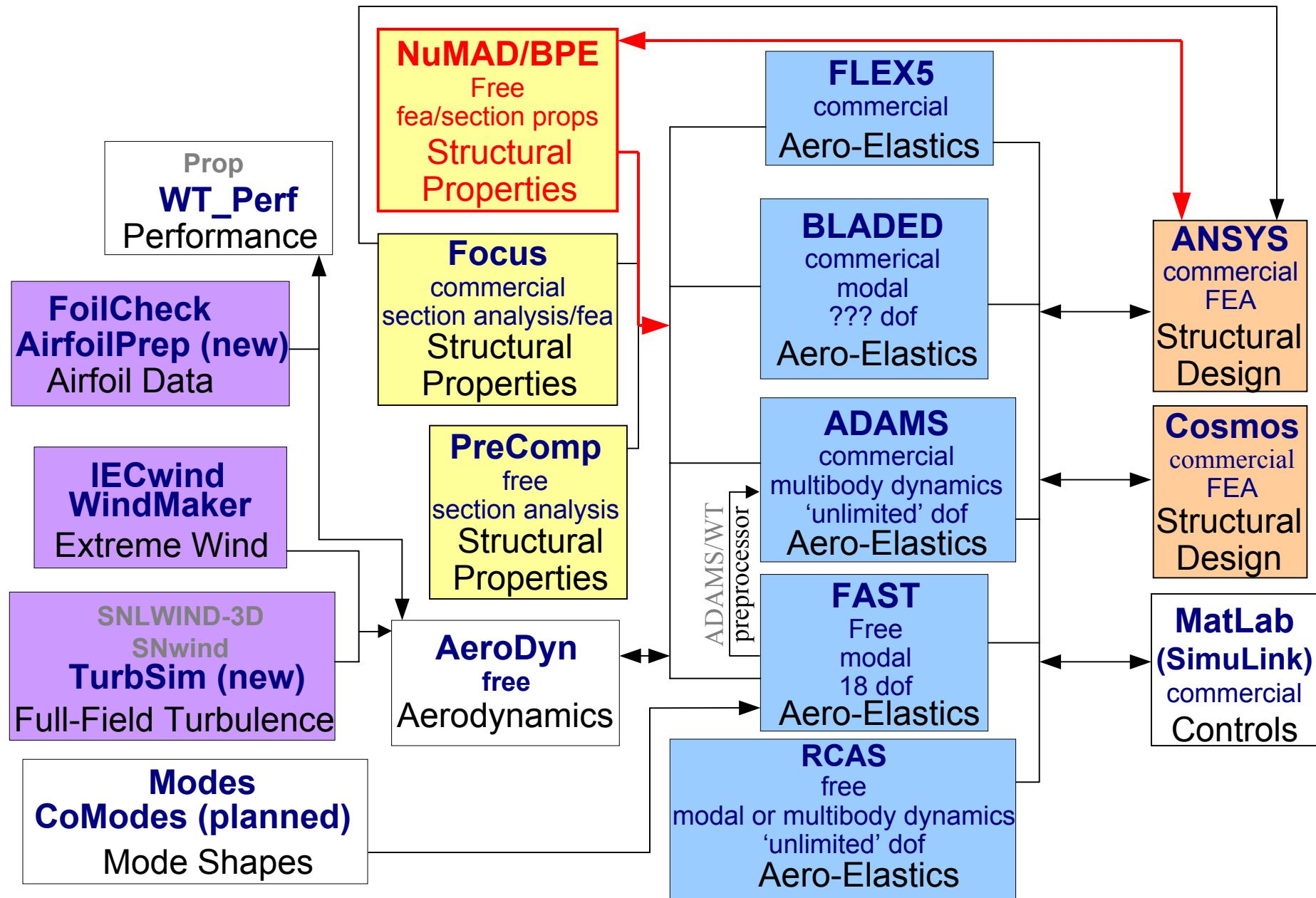
# Design-Process Overview



# Design Codes (U.S. usage)



# Design Codes (U.S. usage)



# NuMAD – Structural FEA Analysis

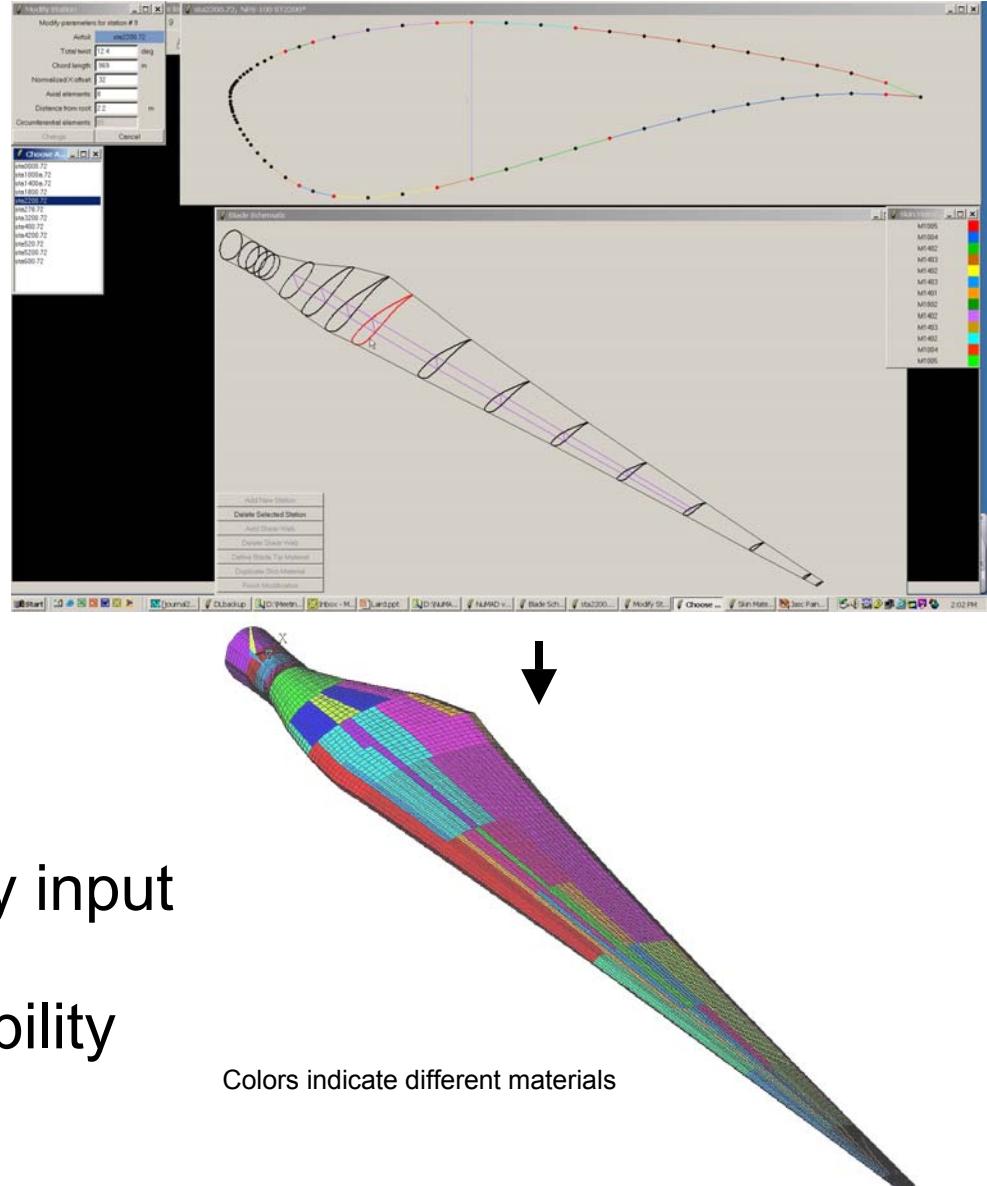
Pre-processor and post-processor for ANSYS®

Tailored to design and analyze wind turbine blades

Databases  
materials  
airfoils  
loadings

Development guided by industry input

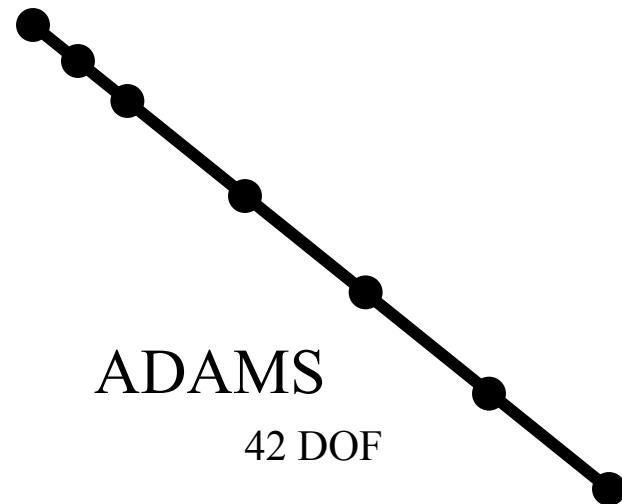
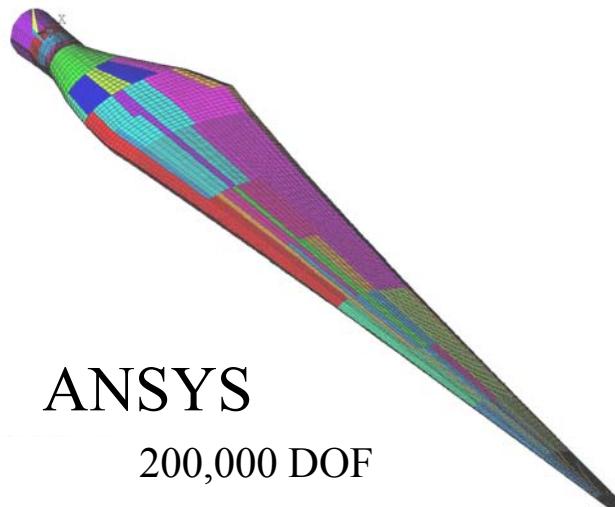
Beam Property Extraction capability



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# Beam Property Extraction (BPE)

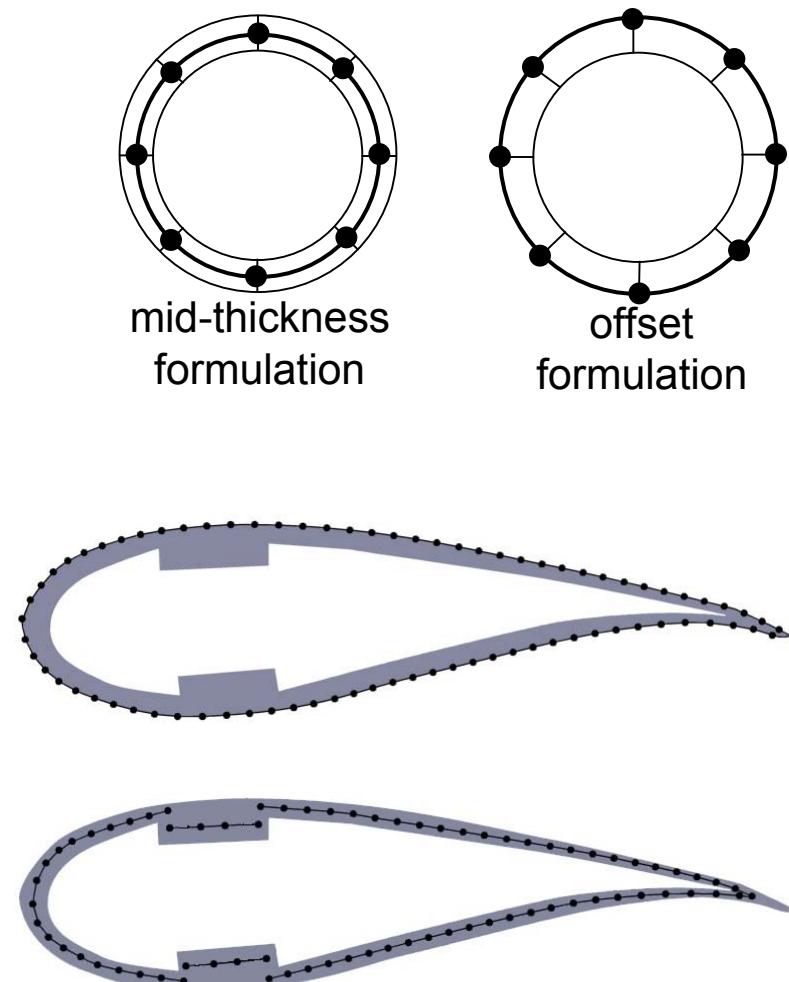
- Joint effort between GEC and SNL
- Goal is to automatically produce the 1-D beam element properties needed for an aeroelastic simulation (ADAMS) from the 3-D structural finite element model (NuMAD/ANSYS)
- May be used with legacy ANSYS blade models



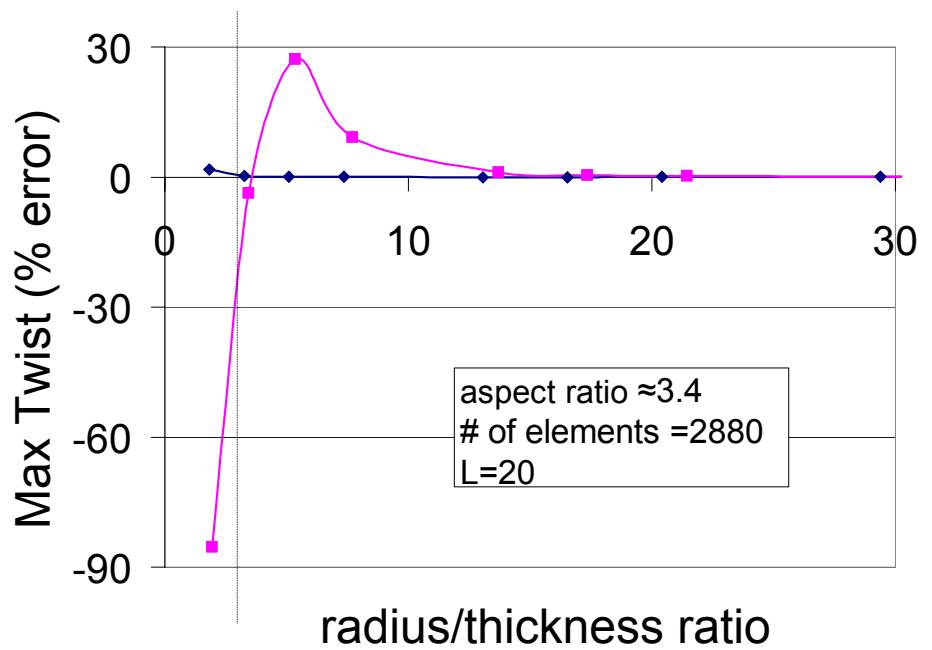
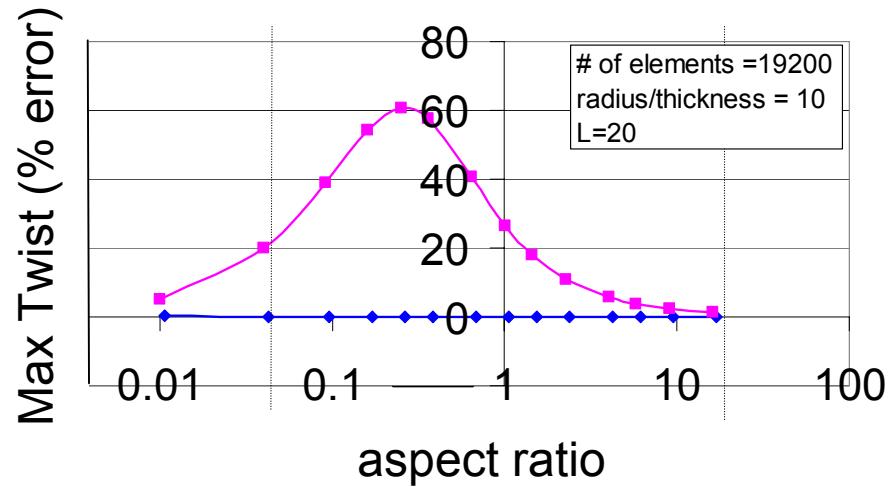
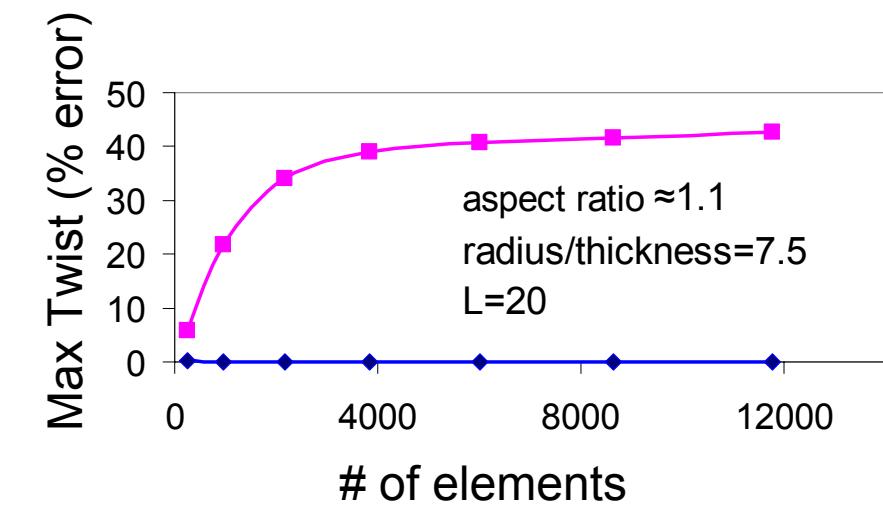
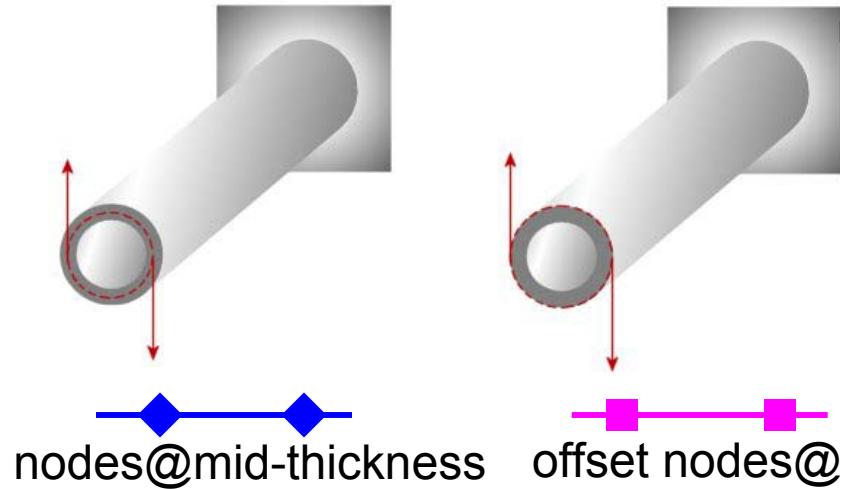
# Finite Element Analysis – Shell Theory

## Nodal Offsets

- Almost all 3-D finite element analyses of wind turbine blades use layered shell elements with offset nodes
- The offset node formulation of the layered shell elements does not correctly handle torsion
- It appears that the issue is a limitation in FE shell theory rather than an error in the particular implementation (i.e. ANSYS vs. NASTRAN etc.)



# Test Case – Hollow Cylinder



# Twist-Bend Coupling (24 hr summary)

Bad News:

“The equations are wrong.”

K. Wetzel

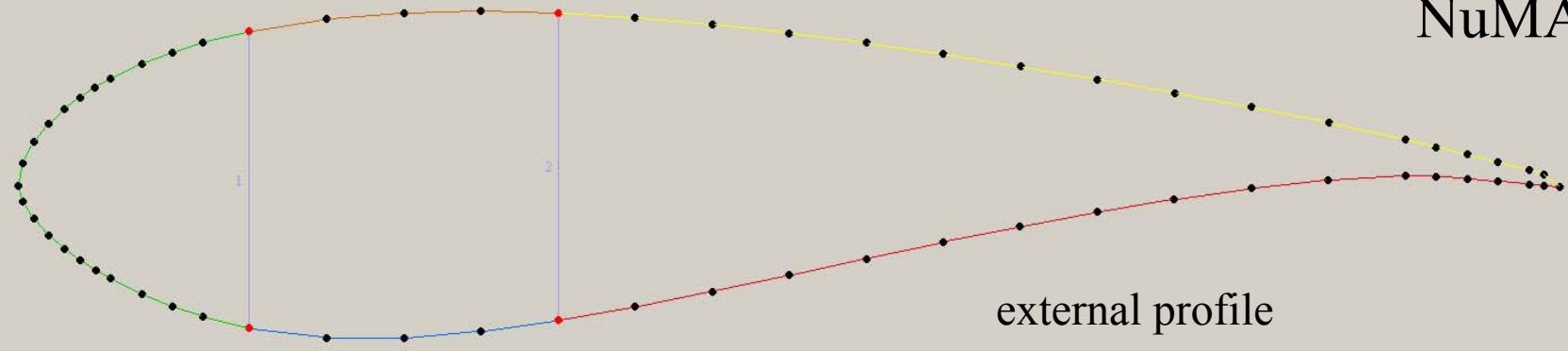
“The simulation is wrong.”

D. Laird

Good News:

Tremendous opportunities for improvement

NuMAD

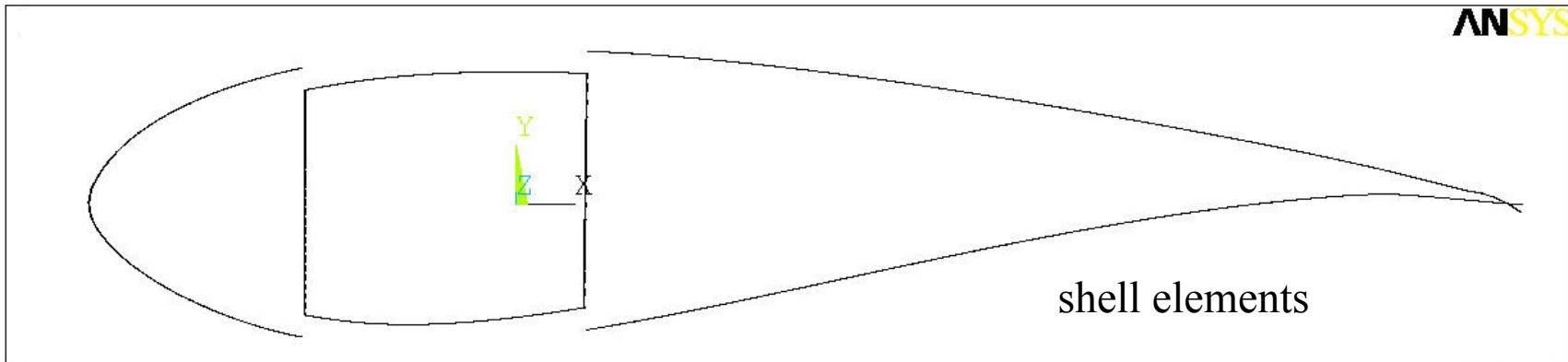


external profile

now produces mid-thickness model

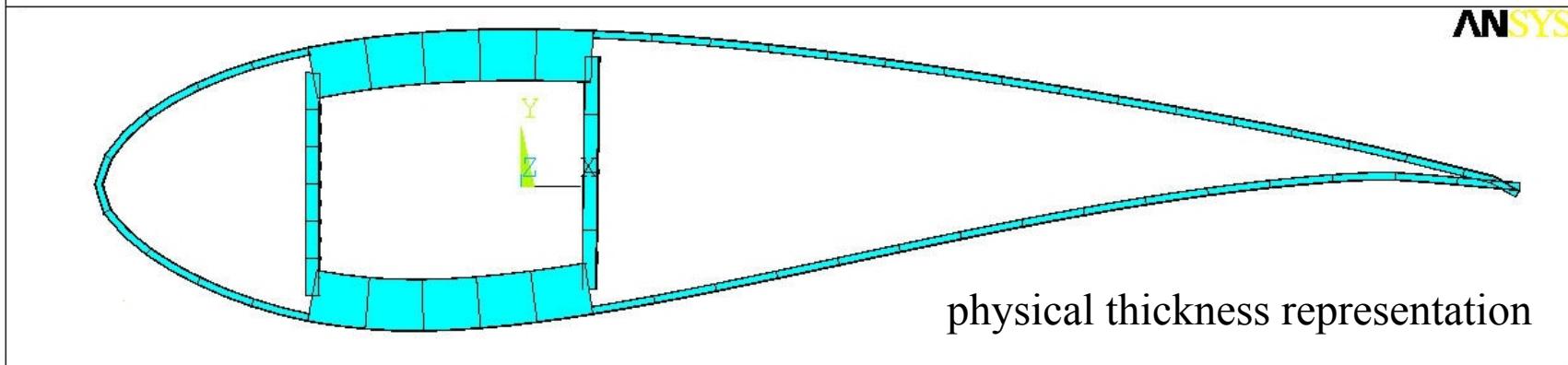


ANSYS



shell elements

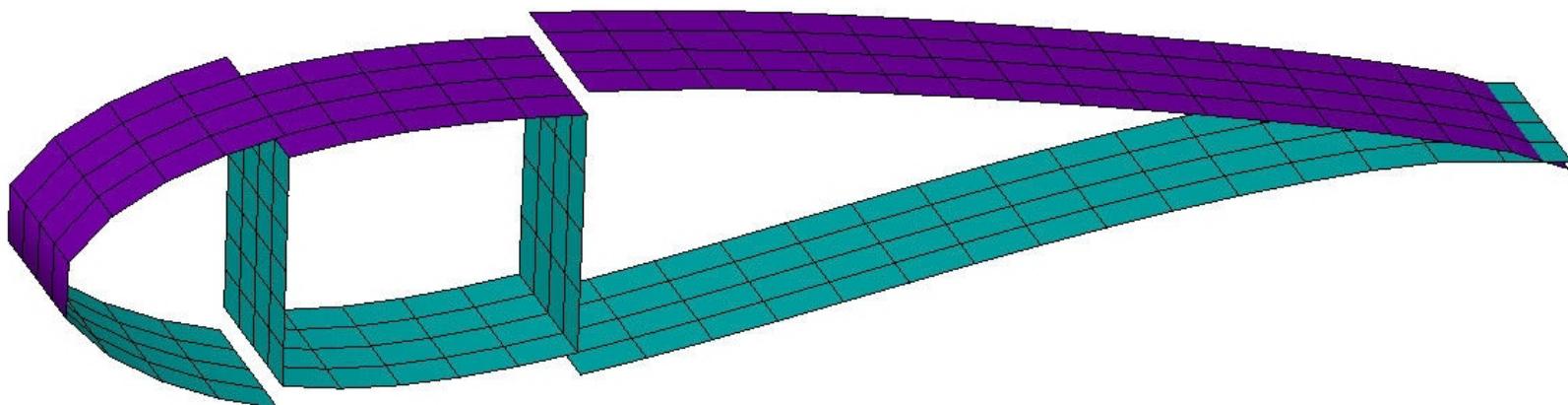
ANSYS



physical thickness representation

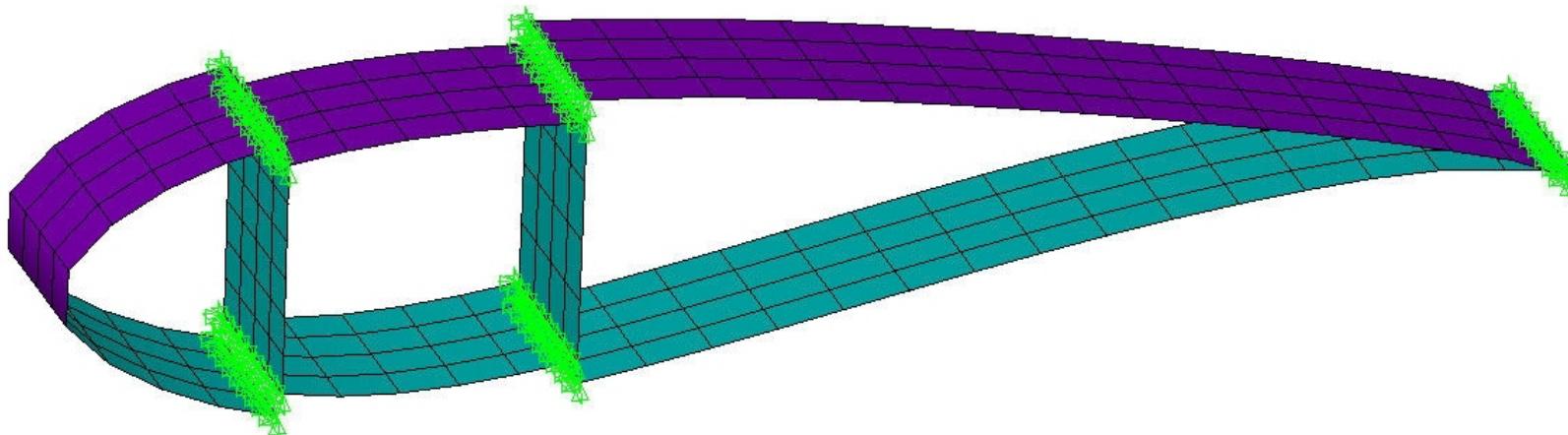
# Glue Together

ANSYS



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ANSYS



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